Shape Memory Alloy (SMA)

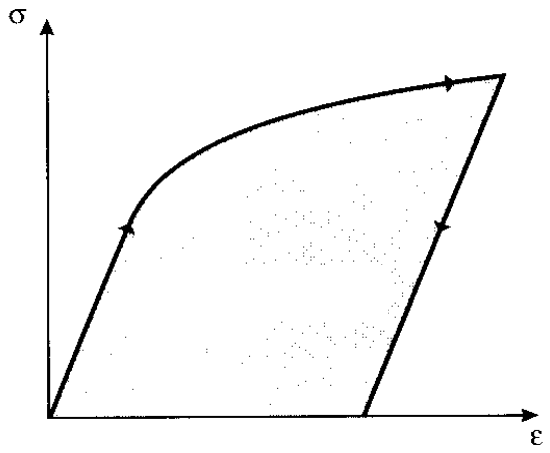
Several figures have been taken from the following references

A review on shape memory alloys with applications to morphing aircraft
S Barbarino, E I Saavedra Flores, R M Ajaj, I Dayyani and M I Friswell, 2014, *Smart Materials & Structures, Vol. 23 063001*

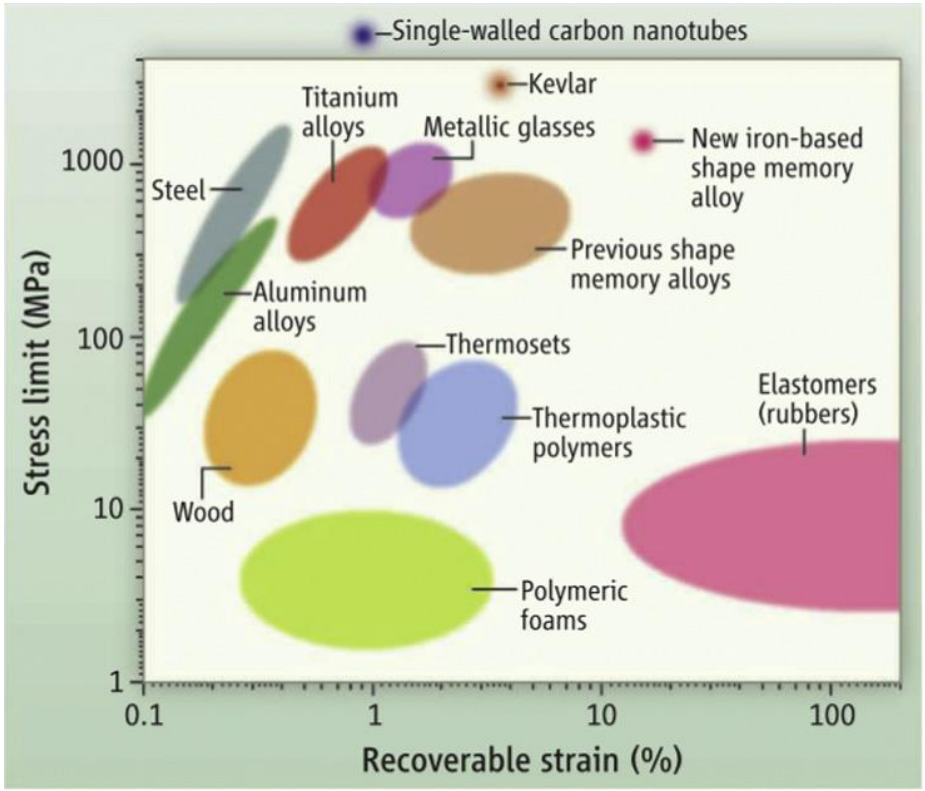
A review of shape memory alloy research, applications and opportunities
Jaronie Mohd Jani, Martin Leary, Aleksandar Subic, Mark A. Gibson,2014, *Materials & Design Vol.* 56 1078–1113

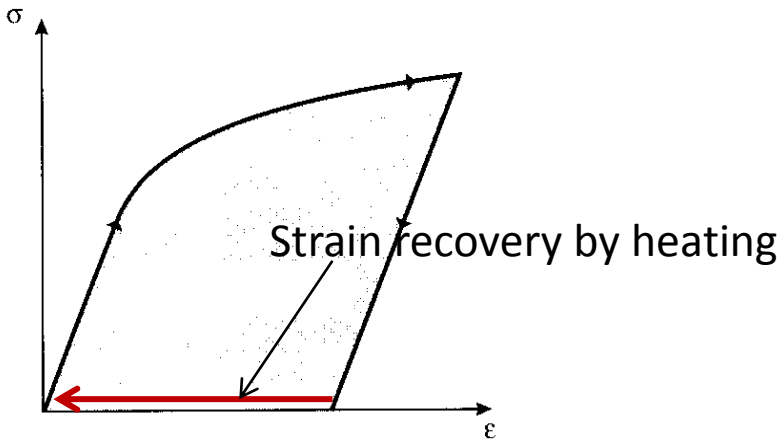
Shape Memory Effect

Shape memory effect is a property by which very large mechanical strains can be recovered by heating the material above a critical temperature

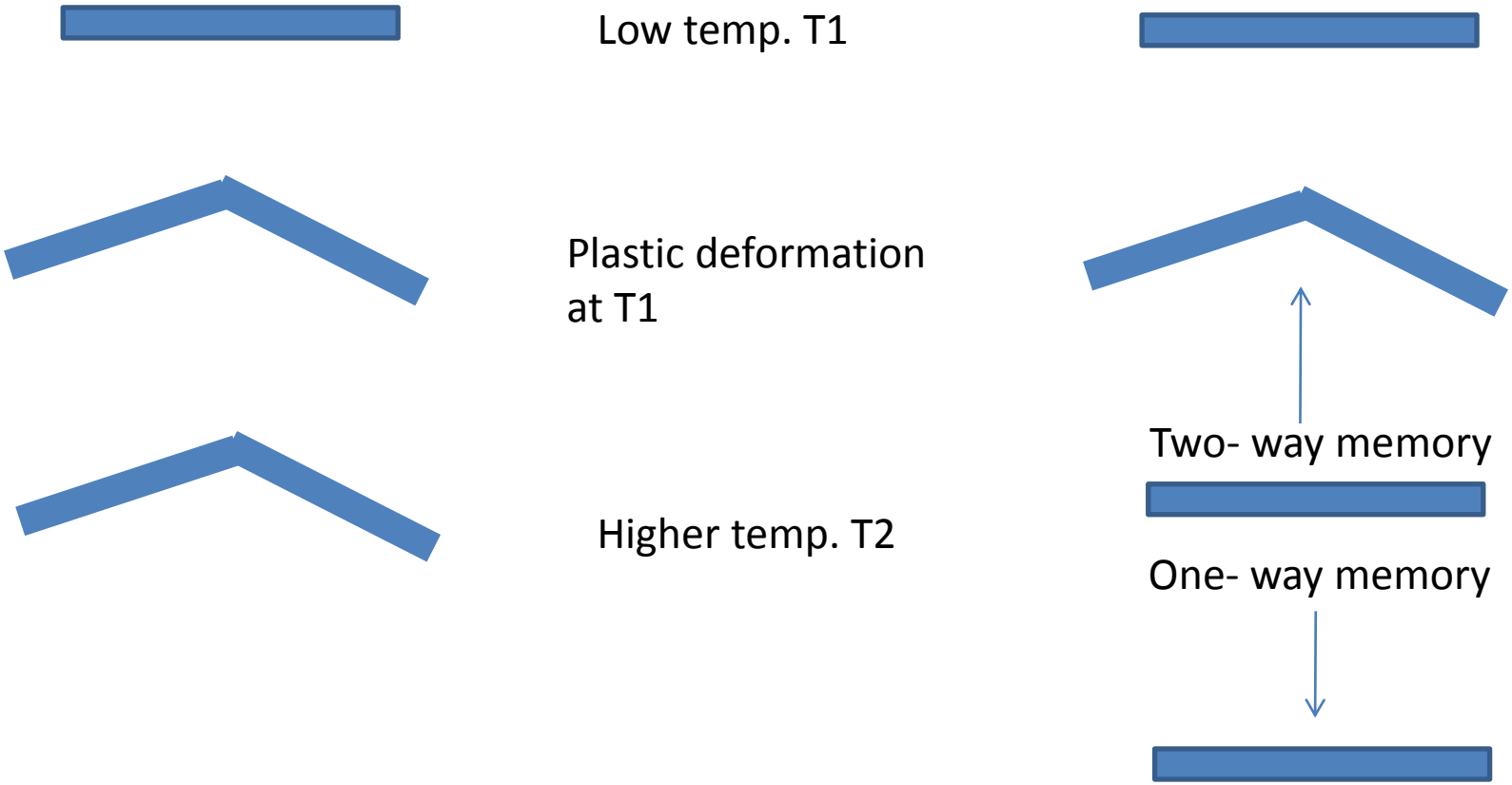


Stress-Strain Curve for a ductile material





Stress-Strain Curve for a SMA



Two way shape memory effect of reversible SME is less applied commercially as It produces about half of the recovery strain and it's shape memory properties deteriorates quickly specially at higher temperatures

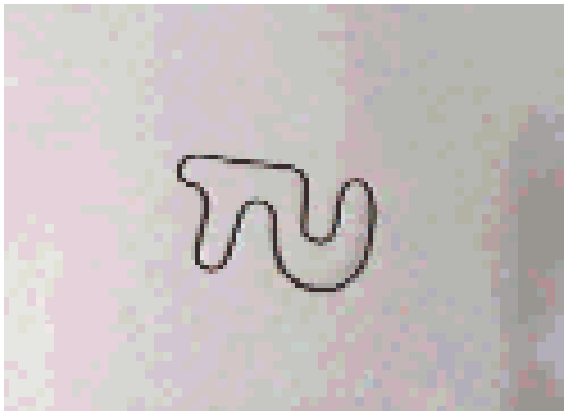
Shape Memory Effects

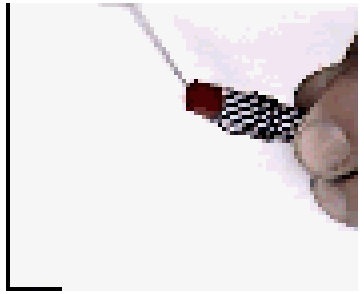
Before plastic deformation
Temp = 20^{o} C

After plastic deformation
Temp = 20^{o} C

After heating
Temp = 50^{o} C

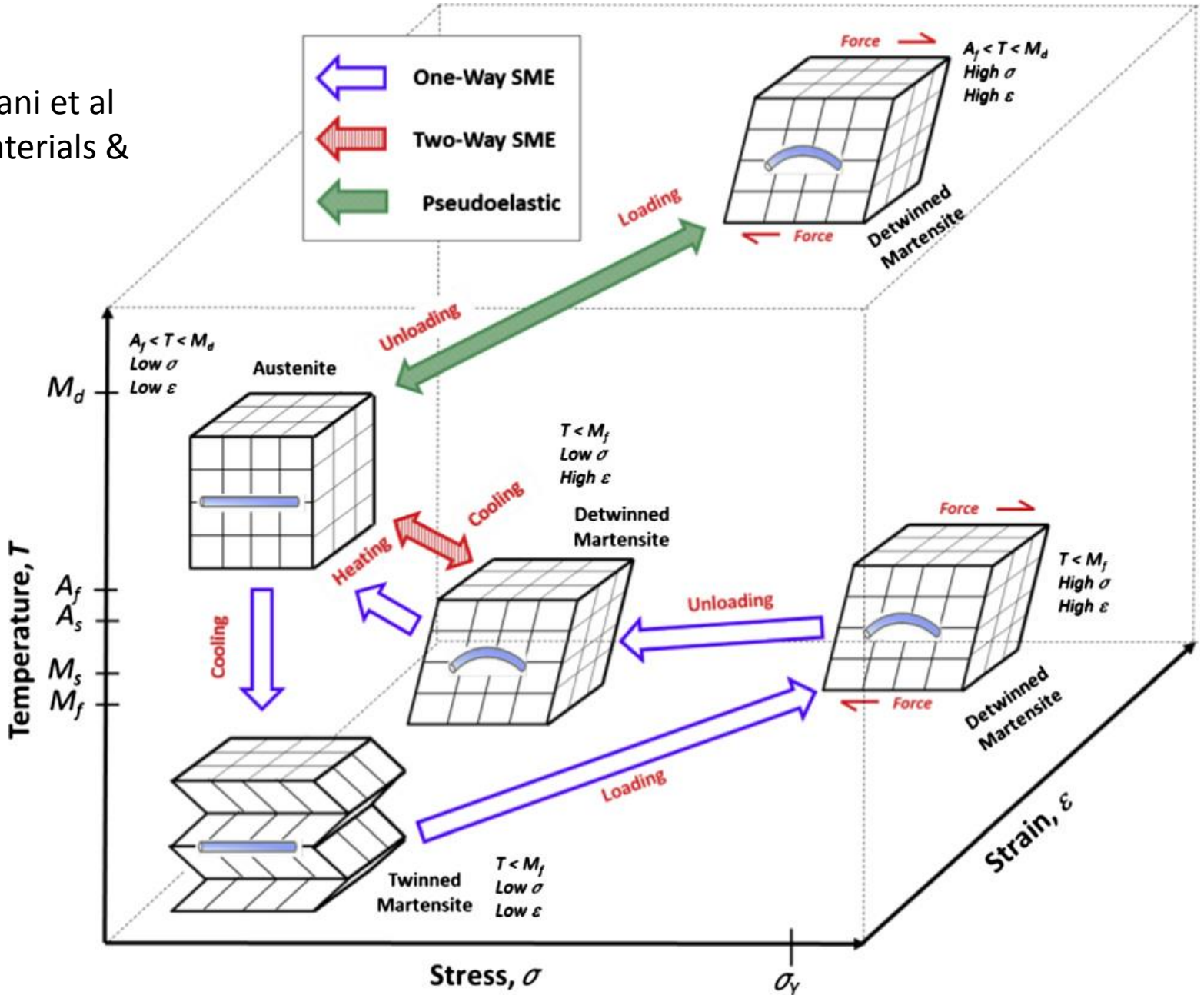
After cooling
Temp = 20^{o} C





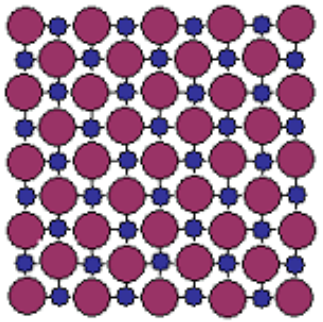
Shape Memory Effect

Source: Jani et al 2014, Materials & Design

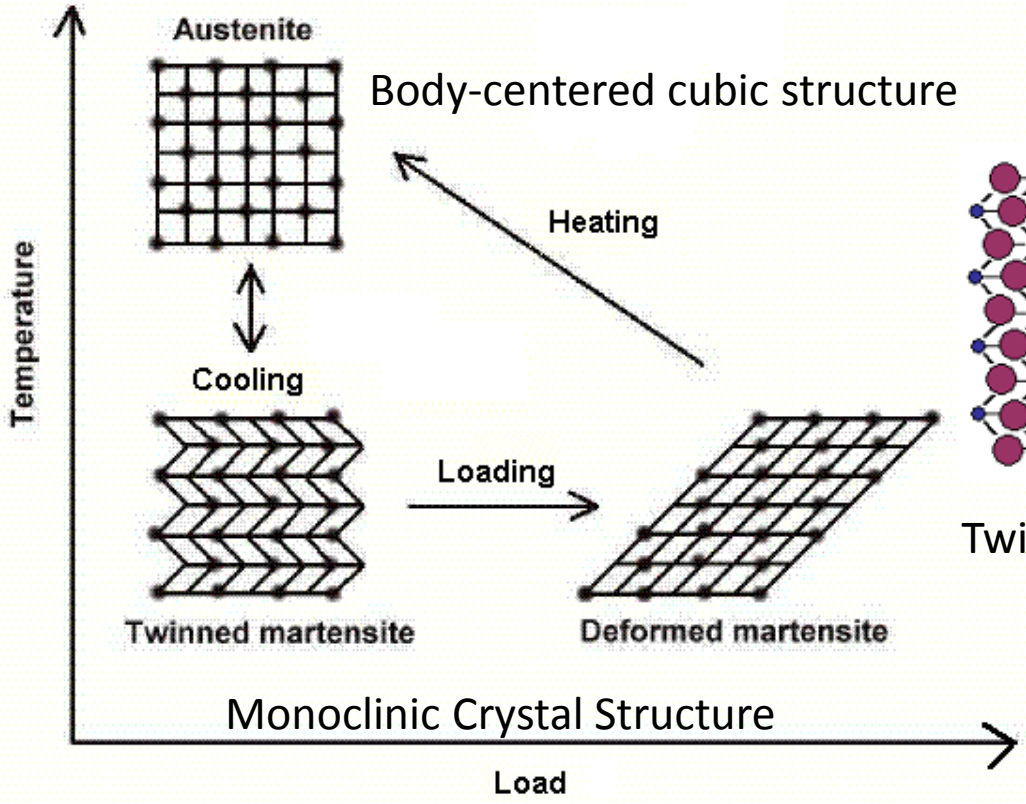


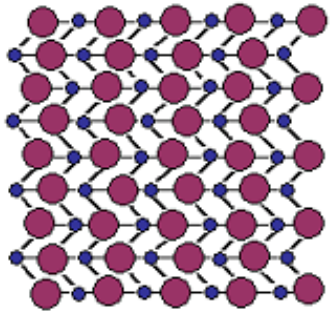
Physical Basis for Shape Memory Properties

Phase Transformation

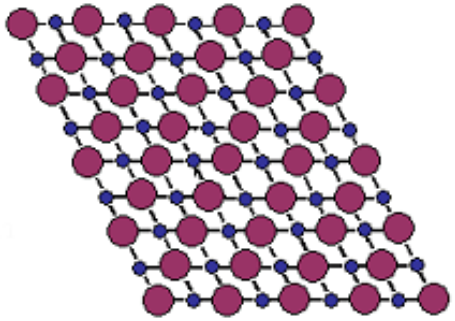


Austenite





Twinned Martensite



Detwinned Martensite

History of SMA Development

- 1932: Shape memory effect (SME) was observed by A. Olander, a Swedish physicist in Gold-Cadmium alloy (Au-Cd)
- 1938: SME was observed in Copper-Zinc (Cu-Zn) & Copper-Tin (Cu-Sn) alloys by Greninger & Mooradian
- 1959: William Beuhler at Naval Ordnance Lab. observed SME in Nickel-Titanium (Ni-Ti) alloy.
- 1962: It was commercialized as NiTiNOL, it was cheaper than other SMAs

William J Buehler

Typical Properties of commercial NiTiNOL alloy

Property	Symbol	Units	Value	
			Martensite	Austenite
Corrosion Resistance	–	–	Similar to 300 series SS or Ti-alloy	
Density	ρ_D	kg/m^3	6450–6500	
Electrical Resistivity (approx.)	ρ_R	μΩ cm	76–80	82–100
Specific Heat Capacity	c	J/kg K	836.8	836.8
Thermal Conductivity	k	W/m K	8.6–10	18
Thermal Expansion Coefficient	α	$m/m\,K^{-1}$	6.6×10^{-6}	11.0×10^{-6}
Ultimate Tensile Strength	σ_{UTS}	MPa	895 (Fully annealed)/1900 (Hardened)	
Young's Modulus (approx.)	E	GPa	28–41	75–83
Yield Strength	σ_Y	MPa	70–140	195–690
Poisson's Ratio	ν	–	0.33	

Limitations of NiTiNOL alloy

Fatigue from cycling

- Causes deformations and grain boundaries
- Begin to slip along planes/boundaries

Overstress

- A load above 8% strain could cause the SMA to completely lose its original austenite shape

Applications